The Influence of Saharan Dust Layers on Convection and Precipitation: A Case Study

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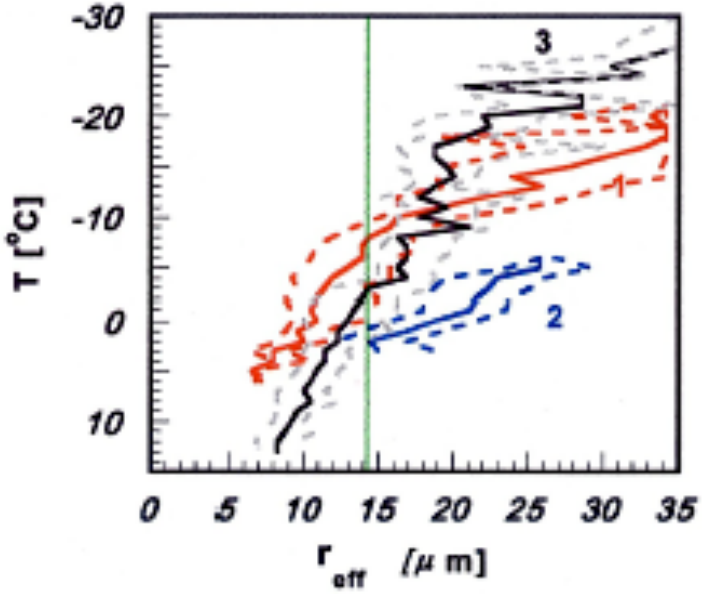
7th CERES-II Science Team Meeting

Newport News, VA 23681, April 24-26, 2007.

Introduction

- Aerosol on clouds and climate:
  - direct -- SW reflection & LW emission
  - semi-direct -- SW absorption, atmosphere heating, & reduction in precipitation
  - indirect effects -- particle size: SW reflection
    longer lifecycle & reduced precipitation

- water clouds: many evidences -- reduce r_e/precip.
  - both Sahara & Asian dusts

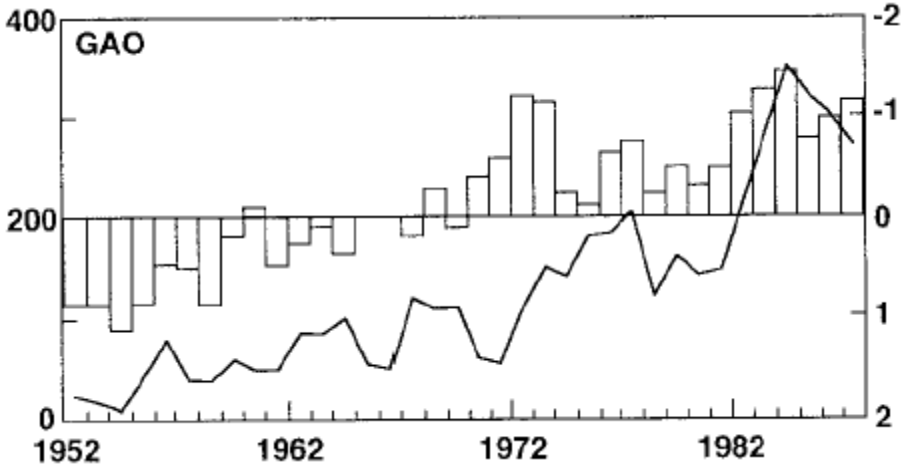


red: clouds in dust areas

blue: dust-free clouds

black: clouds in smoke areas

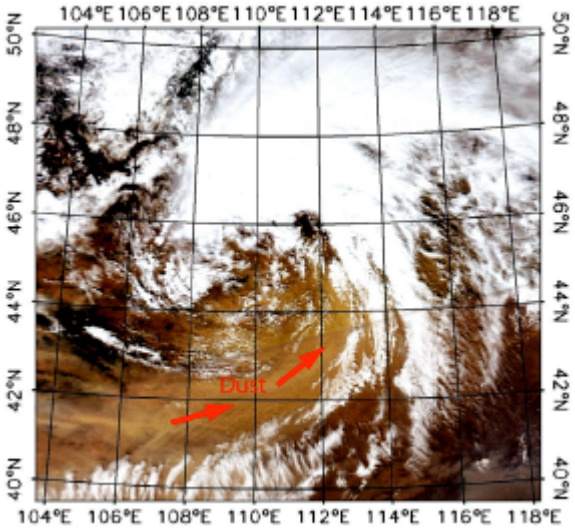
long-term anomalies

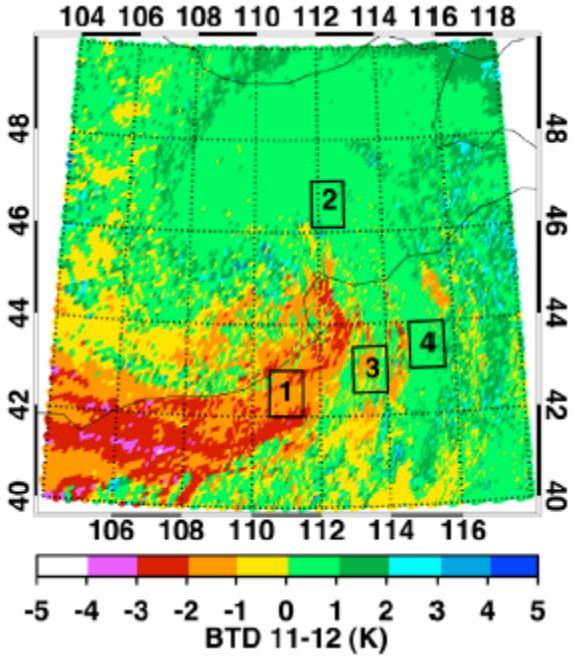


rainfall (bar) &

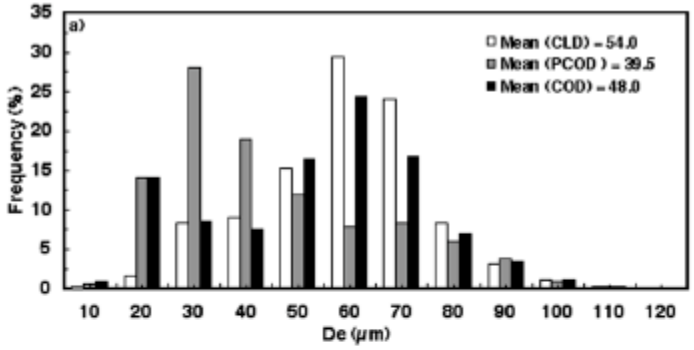
dust freq. (curve)

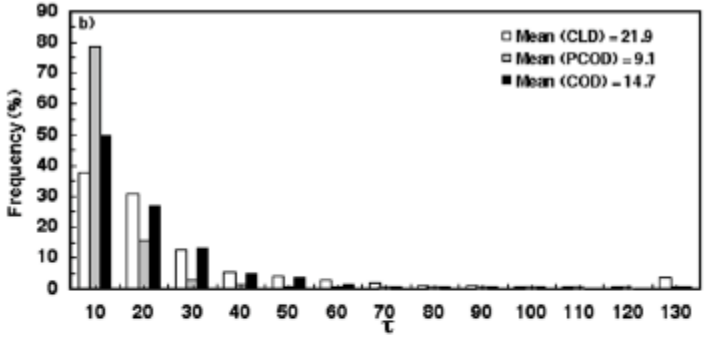
Rosenfeld et al. 2001: PNAS

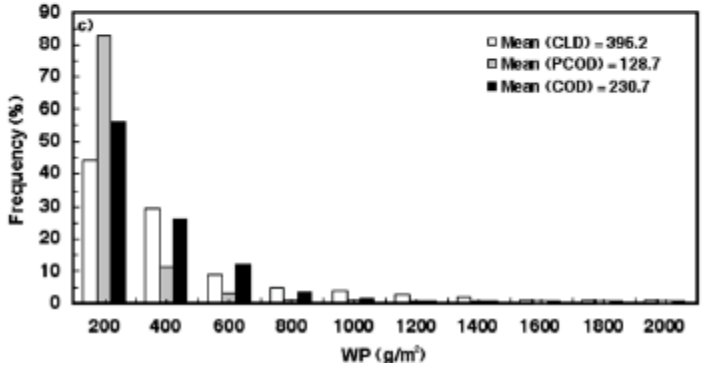


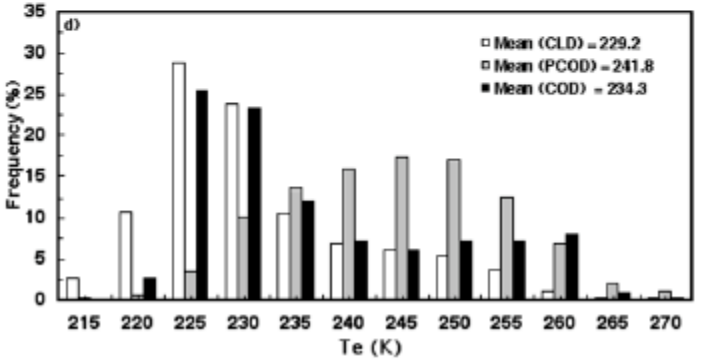


Huang et al. 2006, GRL









Intro: ice clouds

- ice clouds: heterogeneous ice nuclei -- SAL on cloud formation

- upper layer clouds: controversial -- both positive and negative effects of the dusts on tropical storms were proposed.

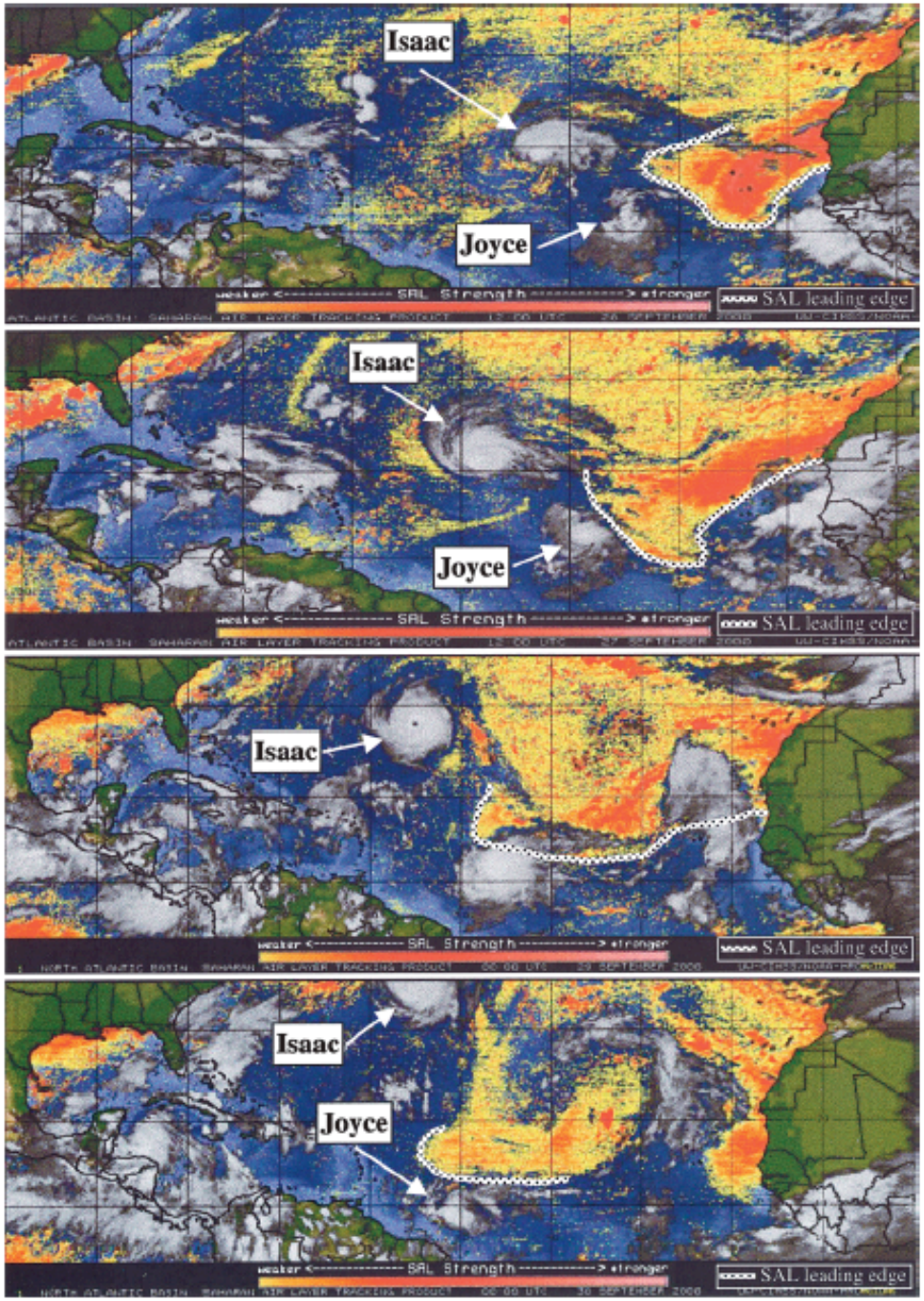
  interacting with the dust layer

- Dust: changing moisture condensation, hydrometeor profile

- influence: moisture supply, dry warm layer, & dynamics

- purpose: differentiate physical processes of dynamic, moisture, and dust from observation data

Dunion and Velden 2004 BAMS



Sept. 26, 2000

Sept. 27, 2000

Sept. 29, 2000

Sept. 30, 2000

Methodology

- Microphysical and dynamical factors:
  convoluted & hard to separate their influences

- Requires:
  special circumstance -- a uniform cloud field
  only perturbed in certain locations by dusts,
  statistical analysis -- large amount of data
  in a specific cloud dynamic regime

- Most large number data: statistics

- case study: shed light on the physics of aerosol-cloud interaction more directly

Data sets

- A case: Saharan dust storm 3/1 – 3/10, 2004.
  trans-Atlantic: 3/1-4 (DF) & 3/7-10 (DS)

- Satellite data: Meteosat-8, TRMM, Terra, Aqua

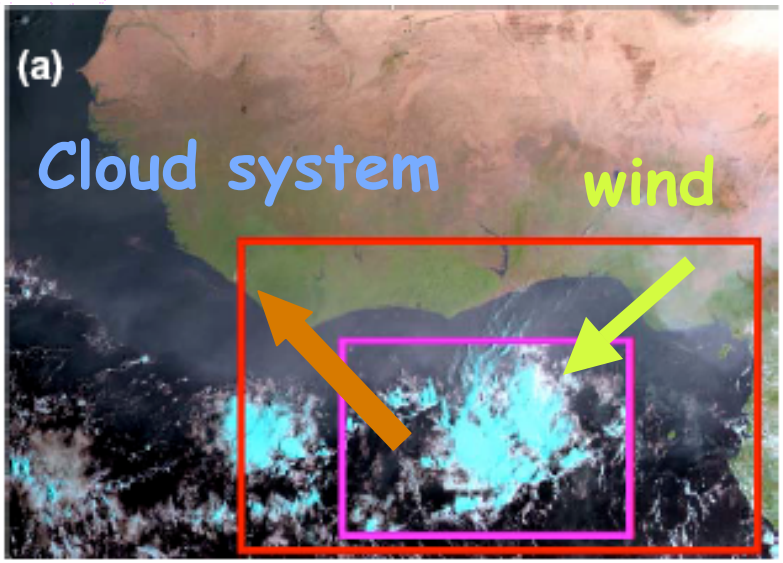
- Surface: AERONET, ship (Ron Brown)
  AERosol and Ocean Science Expedition (AEROSE) mission

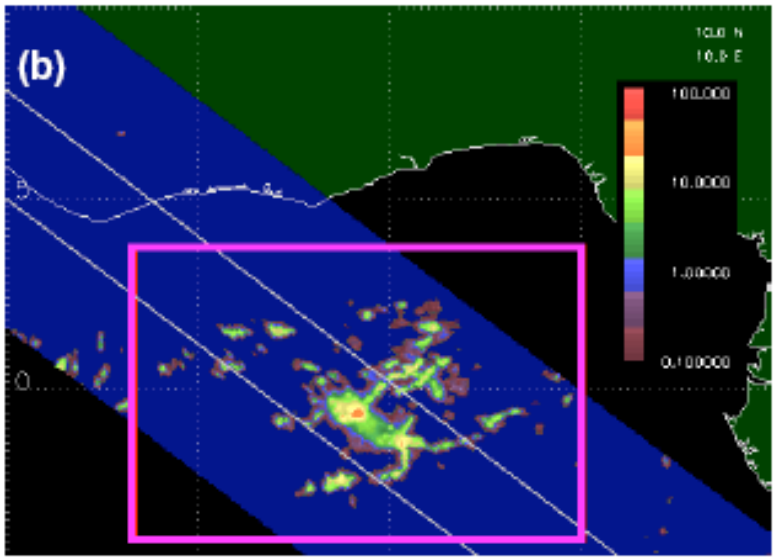
- Assimilation data: NCEP and CRM

- Retrievals: MODIS AOD & CCN;
  TMI rainfall and hydrometeor profiles; PR profiles

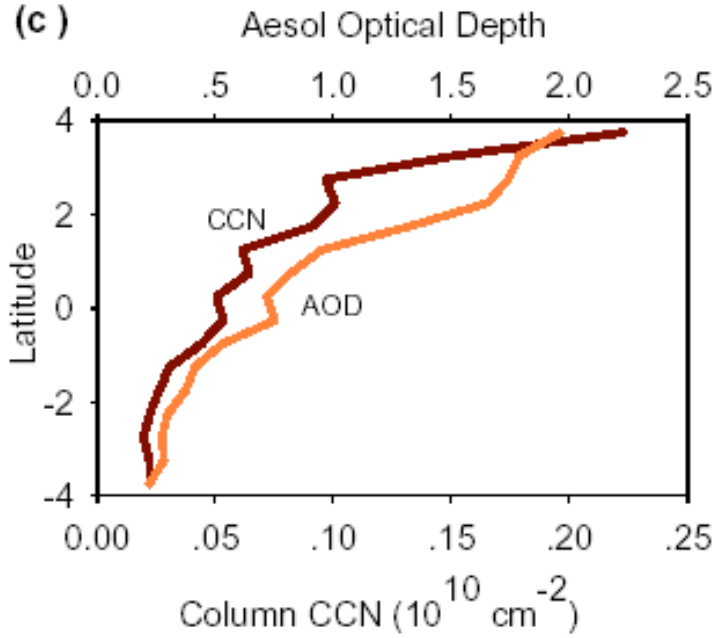
Most of this study are based satellite data

visible & precip. images

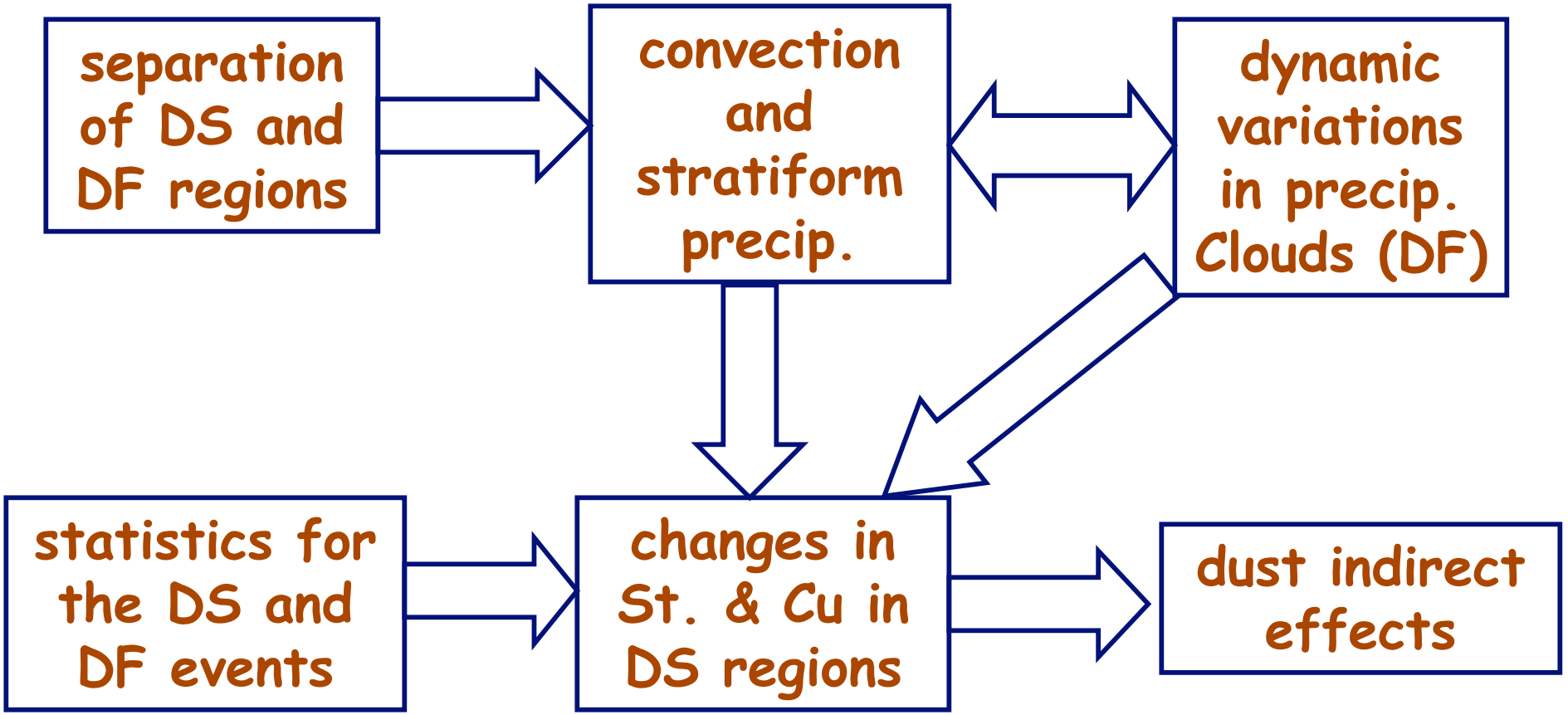




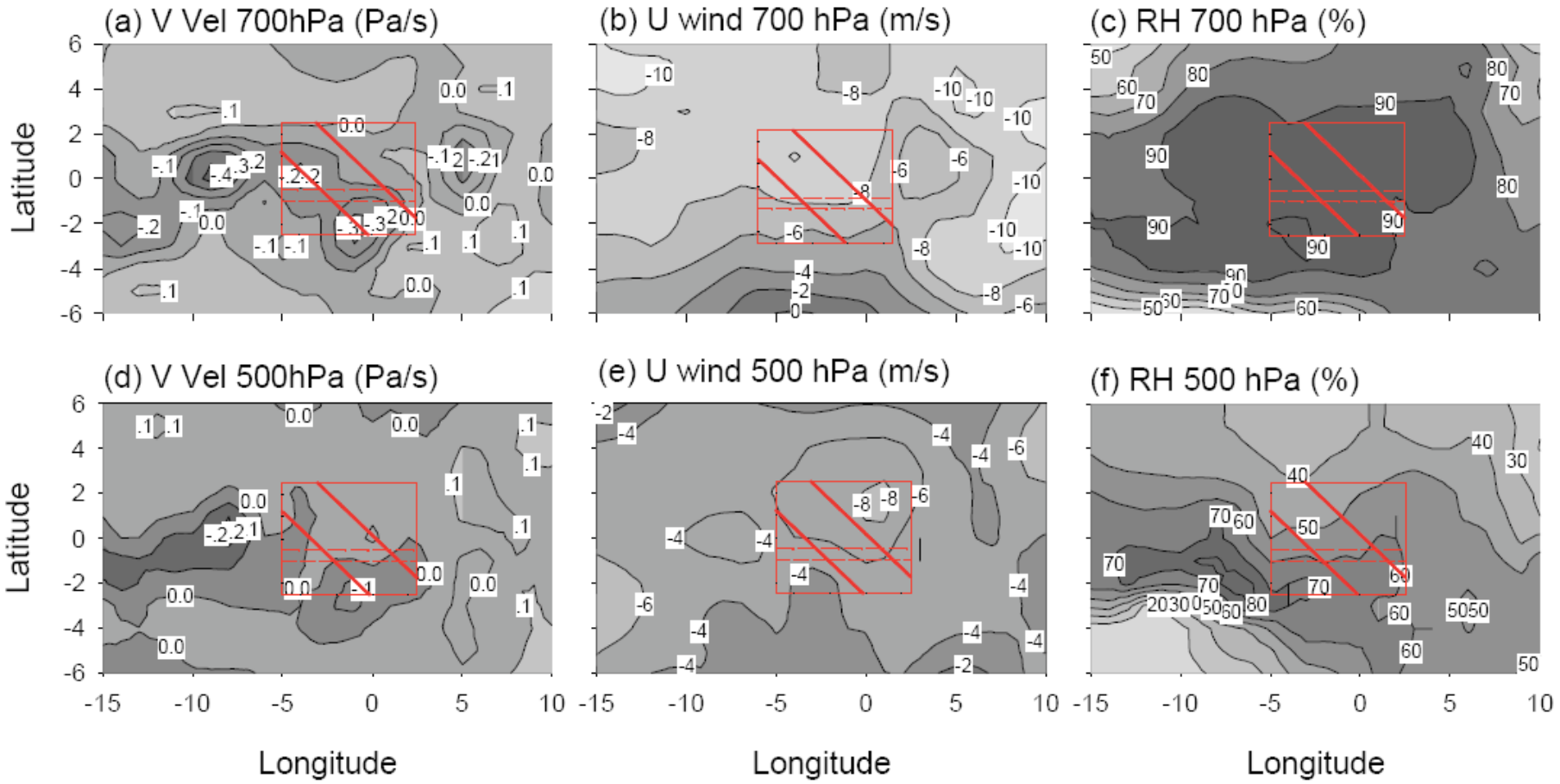
9:12 UTC
March 8, 2004



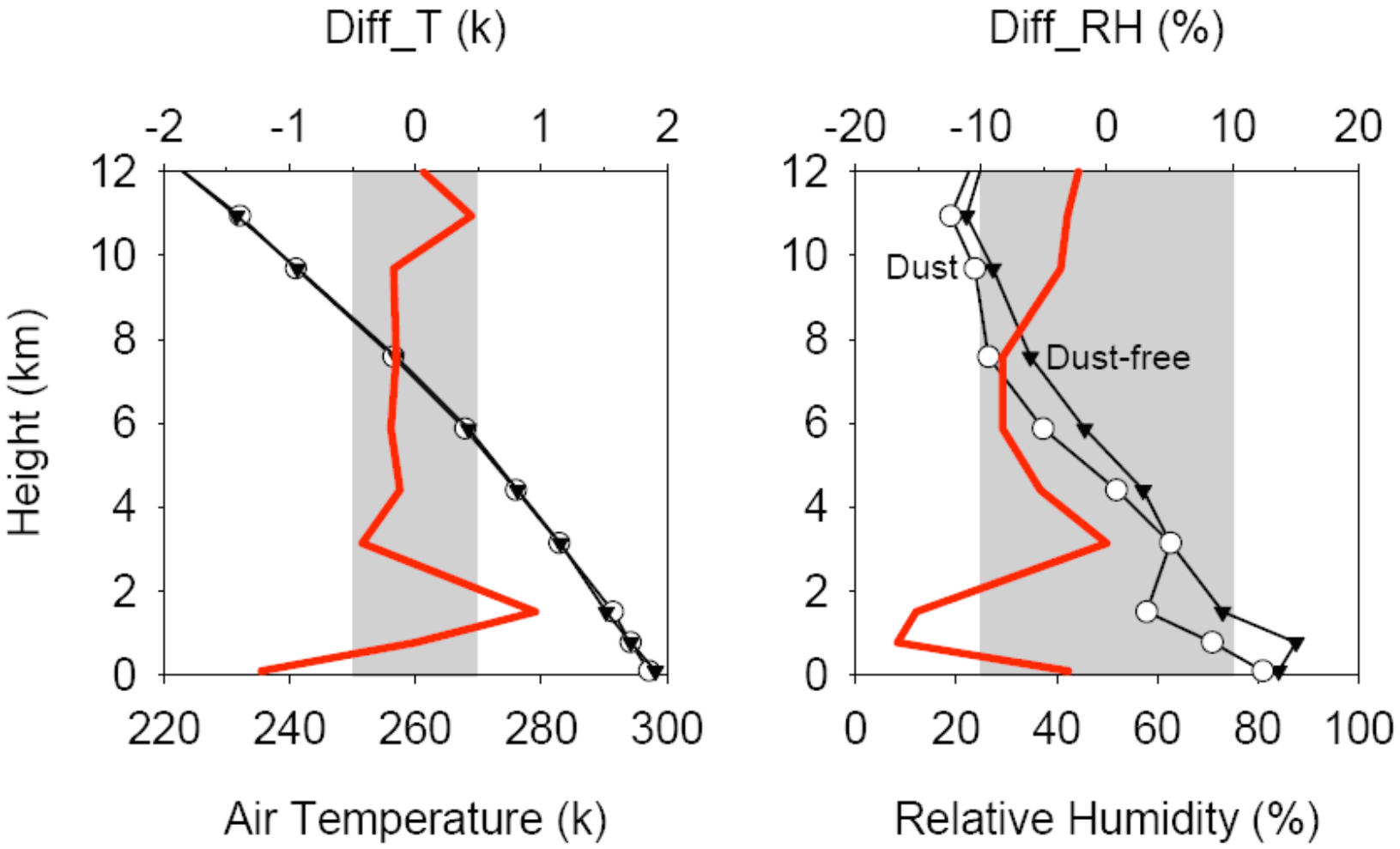
Approach: comparison



dynamic fields

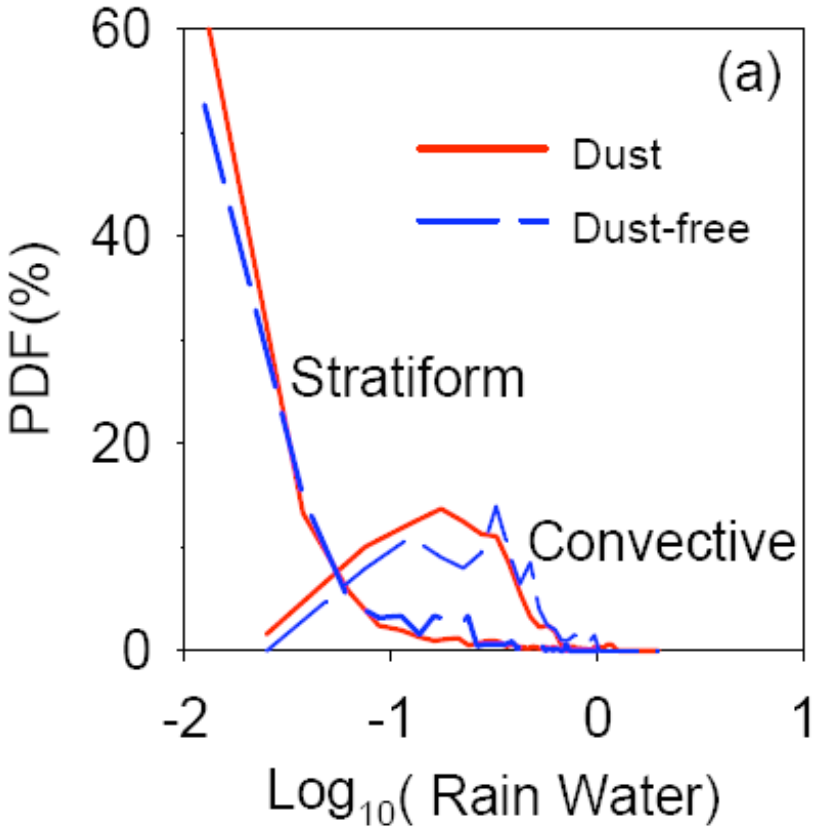


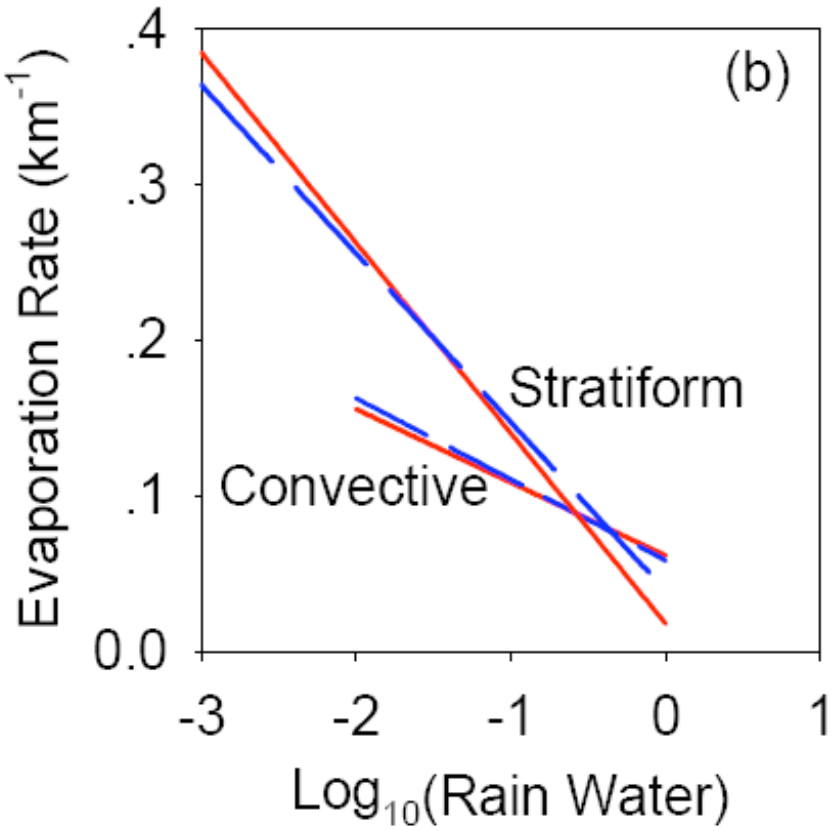
T, q profiles



Aqua AIRS/AMSU measurements

rainwater distribution





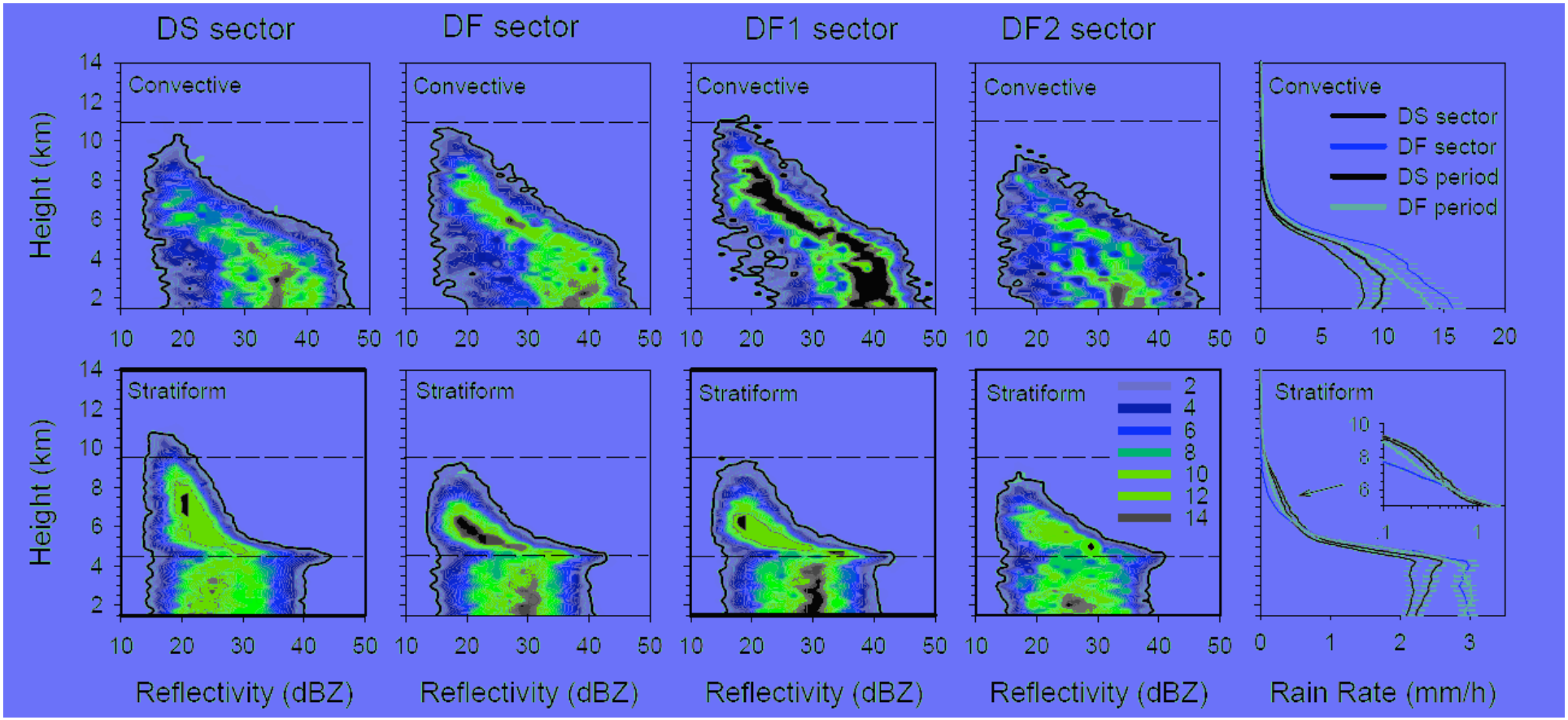
St. rain/ total:
42% (DF); 23 % (DS)

enhanced evaporation:
dry air; weaker precip.

PR vertical profile

instantaneous

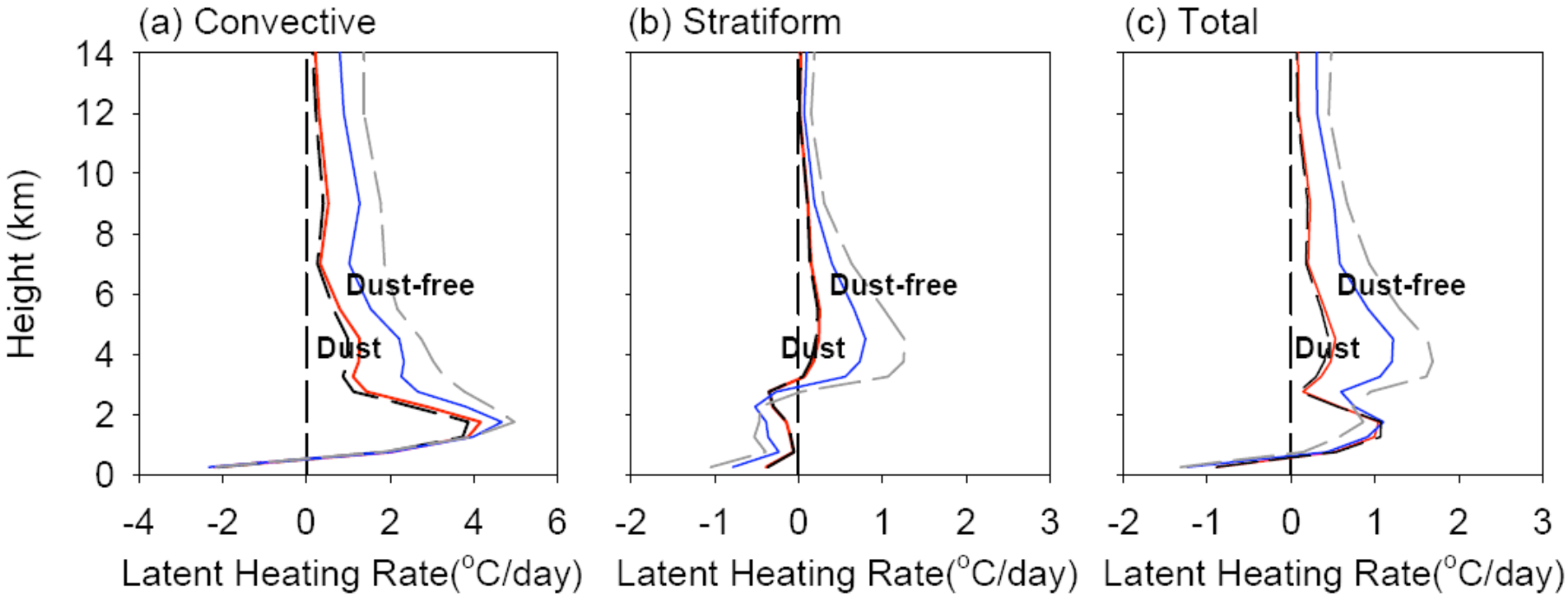
statistics



VSMR of St. precip. regions:
2.4dBZ/km in DS vs 4.3 4dBZ/km in DF

latent heat profile

TMI results



Peak latent heat reduced from 4.5km to 1.8km; weak circulation in stratiform regions

Discussion and summary

- Convective areas: dominated by dynamics; slightly weaker in dusty regions compared to dust-free regions

- Dynamic difference: cannot explain the difference between DS and DF regions
  within the variations of dynamics of DF regions

- Convective and stratiform rains: st. rain fraction 42% to 23%; weaker circulation in straitiform area

- Dusty stratiform area: much more (small) hydrometeors compete less moisture supply; slow growth

- St.: minimal rain & reduced maximum latent heat height from 4.5 km to 1.8km -- evidence of smaller particles

Discussion and summary

- Potential moisture influence: observed reductions in both convective & stratiform precipitation in dusty regions

- Dry air mass: ice amount reduction & possible smaller size due to dry hot Saharan dust layer --NOT observed

- Major dust impacts:

1. weaker precip. due to smaller particles (Indirect Effect);
2. weaker LH heating at upper layers (less moisture supply and weaker circulation in St.);
3. enhanced evaporation (dry air mass at dust layer & smaller hydrometeors)

Acknowledgement

Discussions with R. Li at SUNY-Albany, Y. Hu of LaRC, and others are very helpful for this study. TMI cloud profile data were kindly recommended by Prof. C. Kummerow of CSU.

This research was supported by NASA CERES Mission and EOS and NEWS Projects.